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Construction Materials with Tailings of Quartzite Enrichment

F L Kapustin¹, A A Ponomarenko¹, A M Gorohovskiy² and Z G Ponomarenko²

¹Ural Federal University, 19 Mira street, Yekaterinburg 620002, Russia

²JSC "Pervouralskiy dinasoviy zabod" silica plant, 1 Il'yicha street, Pervouralsk 623103, Russia

E-mail: f.l.kapustin@urfu.ru

Abstract. The composition and properties of the tailings of quartzite enrichment of "Gora Karaul'naya" deposit, the possibility of its using as an aggregate in the composition of heavy and fine- aggregate concrete and dry construction mixture were determined. The introduction of quartzite tailings increases the water demand of the mixture, reduces the compressive strength of concrete and mortar, increases the bending strength compared to quartz sand.

1. Introduction

The quartzite of "Gora Karaul'naya" deposit is used in the production of Dinas refractories on JSC "Pervouralskiy dinasoviy zabod" silica plant. After crushing it is subjected to enrichment with getting standard fraction more than 5 mm and fine fraction of the raw material (enrichment tailings of current output) in the amount of 30-40 thousand tons per year are placed in slurry storage (sludge pond). To date, more than 0.6 million tons of quartzite tailings have been stored in the dump which pollute the natural environment.

The mineral composition of the tailings of quartzite enrichment (TQE) of the current output and TQE selected from the dump is practically similar and is represented mainly by minerals previously described in quartzites and host rocks of the deposit [1, 2]. Tailings are presented mainly by quartz and muscovite impurities in an amount of up to 2 %. As secondary impurities they contain hematite, magnetite, chlorite, shungite, zircon, rutile, iron hydroxides and pyrite with a total content of up to 1 %. Clay lumps in tailings is absent.

Previously performed studies have been established that taking into account the chemical and mineral composition and dispersion the tailings of ferruginous quartzite can be used as coarse and fine aggregate in the composition of structural concretes and backfilling mixtures, as a filler in the production of composite binders and colorful compositions, and iron-poor calcite tailings – in the production of dinas refractories and other materials [3-7]. However the possibility of JSC "Pervouralsky Dinas plant" TQE using as a part of construction concretes was not considered.

2. Raw materials and methods

In the selection of the structural concrete and mortars compositions the following materials were used: Portland cement CEM II-A/S 32,5 N (Russian standard 31108-2016) of JSC "Sukholozhskcement" production; crushed granite fractions 5-10 and 10-20 mm according to Russian standard 8267-93 with the crushability brand equal 1000; sand from screening of granite crushing according to Russian standard 31424-2010; TQE; acid fly ash of Reftinskaya GRES according to Technical Conditions



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5717-004-79935691-2009 and superplasticizer SP-1 according to Technical Conditions 5870-005-58042865-2005 produced by JSC “PoliplastUralSib”.

TQE is characterized by the following composition and properties:

- humidity is 3 %, the average density – 2640 kg/m³; bulk density – 1510 kg/m³, voidness – 42.8 %, the water demand – 10.1 %;
- the content of particles larger than 0.63 mm – 52,3 %, less than 0.16 mm – 15,0 %, quantity of grains of lamellar and needle forms – 24.3 %, quantity of dust and clay particles – 6.2 %; the fineness modulus – 2.8. The grain composition of the TQE meets the requirements of Russian standard 31424-2010 and it belongs to the II class of sands from the screenings of dense rocks crushing.

In the composition selection of the dry construction flooring mix the following materials are used: Portland cement CEM I 42,5 N (Russian standard 31108-2016) of JSC “Sukholozhskcement” production; fractionated quartz sand of 0.16-2.5 mm fraction; the ground granulated blast furnace slag (Technical Conditions 0799-001-99126491-2013) of JSC “Mechel-Materials” production; superplasticizer Melfux 1641 F of “BASF Constraction Polymers”; cellulose ether Mecellose PMS 50UF of “Samsung Fine Chemicals”, antifoam Agitan P813 of “Munzing Chemie”.

Humidity, grain composition, bulk and true density of TQE, crushed stone and fractionated sand were determined according to Russian standards 8269.0-97, 8735-88 and 51641-2000 respectively. Calculation and selection of compositions of fine-aggregate and ordinary concretes were carried out according to Russian standard 27006-86, and determination of their density – Russian standard 12730.1-78, concrete strength – Russian standard 10180-2012.

Concrete properties were compared with the requirements of Russian standard 26633-2012. The mobility of the concrete fine-aggregate mix was determined according to Russian standard 310.4-81, the strength of fine- aggregate concrete was determined on samples of 40x40x160 mm at the age of 28 days and after heat and humidity curing at a temperature of 85 ° C carried out according to the regime: 3 hours heating to a predetermined temperature, 6 hours of isothermal aging and 3 hours of cooling. The mortar properties were determined according to Russian standard 5802-86, they were compared with the requirements of Russian standards 31357-2007 and 28013-98.

3. Results and discussion

The composition of fine-aggregate concrete of B25 strength class with the addition of superplasticizer SP-1 in the amount of 1.0 % by weight of cement was calculated to test the possibility of TQE using as a aggregate. The mobility of the concrete mix was 14.7 cm. Composition and physico-mechanical properties of the concrete are presented in table 1. It is established that the actual strength of fine-aggregate concrete based on TQE with a coefficient of variation equal to 9 % ($V_R=0.09$) corresponds to the specified strength class of B25. The strength of concrete after steaming is 69.8 % of the strength of concrete of normal hardening after 28 days. Thus the TQE can be used as a aggregate in the composition of fine-aggregate concrete. Specific consumption of TQE depends on the concrete strength class, cement and water consumption and can be 1500-1800 kg/m³.

Table 1. Composition and properties of fine-grained concrete based on quartzite tails.

Material consumption (kg/m ³)				W/C	Compressive strength (MPa) after		Concrete density (kg/m ³)
Cement	TQE	SP-1	Water		28 days	Heat and humidity treatment	
432	1626	4	237	0.54	30.5	21.3	2185

To assess the possibility of using TQE and fractionated quartzite sand (0.16-2.5 mm) on their basis as a fine aggregate in the composition of ordinary concrete raw materials and concrete mixture compositions used at the reinforced concrete plant of JSC “LSR.Stroitelstvo-Ural” (Ekaterinburg city)

were used. The mobility brand of concrete mix was P4. The compositions of concrete and the results of determining the properties of concrete mix and concrete are presented in tables 2 and 3 respectively.

Table 2. The composition of the concrete of B30 class strength.

Com posit ion №	Material consumption (kg/m ³)						Fly ash	Dry SP-1	Wa- ter
	Cement	Crushed stone fraction (mm)		Sand					
		5-10	10-20	from screening of crushing granite	TQE	fractionated quartzite			
1	410	435	435	820	-	-	30	1.64	230
2	410	425	425	-	835	-	30	1.64	235
3	400	415	415	-	-	830	30	1.64	237

Table 3. Properties of concrete mix and concrete.

Composition № according Table 2	W/C	Mobility (cm)	Concrete mix density (kg/m ³)	Concrete density (kg/m ³)	Compressive strength (MPa)
1	0.56	21	2360	2335	27.3
2	0.57	20	2360	2307	27.7
3	0.59	20	2330	2332	23.8

It is established that the use of TQE and fractionated quartzite sand does not complicate the process of preparing a concrete mix but to preserve the mobility of the mix it is necessary a greater water consumption (on 5-7 l/m³) compared to the sand from the granite crushing screenings. The density of the concrete mix with granite sand and TQE is the same and the use of fractionated quartzite sand reduces it by 30 kg/m³. Concrete based on TQE and sand from the screenings have a close strength and the use of fractionated quartzite sand reduces it by 14.7 %, which may be due to lower consumption of cement (on 10 kg/m³) and increased water demand of sand. Higher water consumption is associated with the presence in the quartz sand of a significant number of particles of plate and needle shape and the presence of dust-like clay particles on the surface of its grains.

Thus the TQE can be used as a fine aggregate in the ordinary concrete composition. Consumption of TQE in the concrete depending on the quality and consumption of large aggregate can be 750-850 kg/m³. The use of fractionated quartz sand does not worsen the rheological properties of the concrete mix but reduces the compressive strength of concrete compared to concrete on sand from granite crushing screenings.

Verification of the ability to use fractionated quartz sand in the composition of dry construction mixtures was carried out on the example of the dry mixture for the floor screed in accordance with Russian standard 31358-2007. The control composition of the mix was prepared using fractionated quartz sand having the same grain composition with quartzite sand (table 4). The following composition of the dry mixture, %: 24.6 Portland cement CEM I 42.5 N; 73.9 sand, 1.29 granulated blast furnace slag; 0.085 superplasticizer Malfux 1641 F; 0.025 cellulose ether Mecellose PMS 50UF; 0.1 defoamer Agitan P813 is used.

The amount of water for the preparation of the mortar mix from the dry mix was selected at the same mobility of Pk2 (the actual cone immersion value is 4.2 cm). It is established that using of quartz sand the water-cement ratio was 0.43; quartzite sand – 0.66, i.e. the dry mix on its basis is characterized by increased water demand. The actual composition of the mortar based on quartz and quartzite sands is presented in table 5, the results of determining of the physical and mechanical properties of the mortar – in table 6.

Table 4. Granulometric composition of fractionated sand.

Sand	Quantity of fractions (%)			
	1.25-2.5	0.63-1.25	0.315-0.63	0.16-0.315
Quartzite	28.91	35.39	20.68	15.02
Quartz				

Table 5. Composition of mortar.

Com- posi- tion №	Ce- ment	Material consumption (kg/m ³)						Water
		Sand		Crushed blast furnace slag	Superplas- ticizer Malfux 1641 F	Cellulose ester Mecellose PMS 50UF	Defoamer Agitan P813	
1	520	quartz	quartzite	6	0.44	0.130	0.52	225
2	500	-	1500	6	0.425	0.125	0.50	330

Table 6. Physical and mechanical properties of mortar.

Composition № according Table 5	Density (kg/m ³)		Bending / compressive strength (MPa) after (days)	
	mix	mortar	3	28
1	2322	2243	5.6 / 39.4	7.4 / 52.5
2	2337	2209	6.1 / 33.7	8.7 / 48.8

It was found that in the early stages of hardening in air-wet conditions the mortar on quartz sand is characterized by lower bending strength (8.9 %) and greater compressive strength (16.9 %) compared with the mortar on quartzite sand. Further hardening up to 28 days retains the predominant bending strength and reduced compressive strength of the mortar on quartzite sand. In this case the difference in compressive strength of the mortar on quartz sand compared with quartzite does not exceed 7.6 %. The investigated composition of flooring dry mix on the quartz sand has a class on the compressive strength of B40, bending class – Btb5,2, and on quartzite sand – Btb5 and B35,2 respectively. Thus quartzite fractionated sand is recommended to be used in the composition of dry construction mixes for which the bending strength and crack resistance is of primary importance for example for the manufacture of flooring concrete or mortar coatings, plaster mortars, etc.

4. Conclusion

The tailings of quartzite enrichment of JSC “Pervouralsky dinas plant” can be used as a aggregate in composition of heavy and fine-aggregate concrete, dry construction mix for a flooring covering. However the introduction of TQE reduces the compressive strength of concrete and mortar and increases the bending strength compared to quartz sand.

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